vWorld capability development support

Literature survey

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VWORLD CAPABILITY DEVELOPMENT SUPPORT LITERATURE SURVEY

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Version 02	Revisions based on DRDC's comments.	24 June 2014

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EXECUTIVE SUMMARY

CAE Inc. was contracted (Solicitation No.W7707-135643/B) by Defence Research and Development Canada (DRDC) to conduct a literature survey regarding the use of OpenSIM or similar Virtual World (vWorld) technologies to develop and review system designs such as compartment layouts and team processes on naval platforms, particularly when stakeholders from the Department of National Defence/Canadian Armed Forces (DND/CAF) are distributed. For the purpose of the literature survey reported herein, a vWorld is a computer graphical representation of three dimensional, physical environments that users may interact with by controlling computer generated agents (often referred to as avatars) or with agents controlled by other users[1]. The scope of the literature survey was to focus on the use of OpenSIM and to discuss:

a. Convergent and divergent trends;

b. Active user community and applications;

c. The use of OpenSIM in support of system development for: Navy operations, Navy training, other military operations and training, real-time defence and security (e.g., emergency operations) or other real-time, operational, complex, high-risk environments;

d. How OpenSIM can be linked to other analysis tools; and,

e. How OpenSIM has been linked to other applications (CAE, 2013b).

Only 10 documents were reviewed in depth due to constraints on the level of effort of the contract; 75 abstracts were reviewed to determine a broader impression of the vWorld domain. Only a few of the documents referred to OpenSIM explicitly and none provided a great deal of detail on how each OpenSIM application was created; instead the reviewed reports focused on the use of vWorlds.

The conclusions of this work are:

a. Several vWorld platforms are available that could be and are being applied to military domains (at least on an experimental basis) including: Second Life, OpenSIM, Virtual Battle Space 2 (VBS2) / VBS3, Active Worlds, Croquet, On-Line Interactive Virtual Environment (OLIVE), Open Colbalt Alpha, OpenEnergySim, Open Wonderland, Pivote and Teleplace;

b. Converging trends reveal that OpenSIM is being demonstrated as a capable and flexible platform. There is an active OpenSIM user community in the application domains of interest to DRDC (Section 3.2) including organizations such as: US Naval Undersea Warfare Center (NUWC), Australian Defence Science and Technology Organization (DSTO), the US Navy Postgraduate School, Florida Institute of Technology (Harris Institute for Assured Information), University of Edinburgh (Artificial Intelligence Applications Institute), and the US Army;

[1] Summarized from Wikipedia: http://en.wikipedia.org/wiki/Virtual_world

c. OpenSIM can support diverse applications including systems development and training, and the number of institutions exploring vWorlds in general seems to be increasing as awareness of the technology increases. However, the scientific literature assessing the validity of vWorlds for training or analysis is immature and the effectiveness of these technologies remains to be determined;

d. Research and development or at the very least knowledgeable analysis is needed to match training requirements to evolving vWorld capabilities in order to establish the validity of a vWorld for the intended training application. Much of what is known about the effectiveness of simulation-based training should be applicable, but there are many misconceptions held by education practitioners;

e. Basic research is needed to develop open architecture (OA) frameworks for specifying vWorlds to promote exchange and reuse of models as well as reduce the incidence of models that cannot be exchanged between virtual environments (Scacchi & Alspaugh, 2008; Scacchi, 2012); and,

f. OpenSIM can be linked to other analysis tools through an Application Programming Interface (API).

Recommendations are:

a. Employ a user centred design approach to develop tools fit for use in vWorlds for the purpose of systems development and training. In accordance with guidance from MIL–STD–46855A, the Mission, Function, and Task Analysis (MFTA) methodology has been widely used within the Human Factors community to conduct analyses of user requirements for over twenty years. Suggested capabilities derived from the reviewed literature that should be provided by a vWorld to support systems development and training effectively are documented in Section 4.1.2 and Section 4.2.2, respectively;

b. Conduct a number of use-case experiments that compare vWorld development to conventional design methods to assess the relative costs and effectiveness of immersive environments for design. The use-cases should be sufficiently challenging that they can discriminate between the design approaches, but limited in scope so that they could be conducted in an affordable manner. Further, the experimental design should explicitly include adequate training in both traditional and vWorld design methods to minimize biases due to learning the methods per se (Scipione, 2006);

c. Employ a disciplined, instructional design approach before considering vWorlds as a potential solution for training delivery;

d. Conduct a directed investigation of training effectiveness. Effective training typically requires a disciplined application of instructional design, applying what is known about how people learn, how learning can be disrupted and how technologies support learning; and,

e. Validate the use of OpenSIM for learning and training by employing transfer of training analysis methods as prescribed by AGARD (1980).

1 INTRODUCTION

This literature survey report was developed by CAE Inc. (CAE) for the Defence Research and Development Canada (DRDC) – Atlantic project entitled “vWorlds Capability Development Support” under contract #W7707-135643/001/HAL.

1.1 Background

Virtual Worlds (vWorlds) are interactive simulated environments accessible by multiple distributed users through an online interface. Human representation typically takes the form of human avatars that are computer representations of agents that the user can control to interact with the virtual environment[2]. vWorlds have seen increasing usage for several purposes. The largest and most common use of vWorlds is for commercial gaming or Massively Multiplayer Online Role Playing Games (MMORPG) such as World of Warcraft and Everquest. However, vWorlds have also seen application in the domains of education and training, community building, tourism, and e-commerce. For commercial applications that seek a world-wide market, persistence of the vWorld is an important feature. Persistence entails that vWorlds endure (as-is) when powered off and on again without the need for a user to explicitly save the vWorld state. For specific military applications, persistence may not be an important feature as much as distributed-user access and so this review was not constrained to virtual environments that are generally considered to be persistent.

Defence Research and Development Canada (DRDC) is interested in the use of vWorlds to enable the Department of National Defence/Canadian Armed Forces (DND/CAF) to develop and review system designs such as compartment layouts and team processes on naval platforms (Solicitation No.W7707-135643/B).

1.2 Objective

The objective of the contract is for CAE to provide support to a two year agility project to develop a capability to use vWorlds at DRDC Atlantic (Halifax, NS) and DRDC Toronto and to demonstrate the application of vWorld technologies to naval projects. The support is required to cover:

- Provision of training on the Open Simulator (OpenSIM) vWorld technology (CAE, 2013a);
- Conduct of studies of the interoperability of OpenSIM with other DND/CAF simulation technology (CAE, 2013b); and,
- Conduct of a literature survey (reported herein) intended to inform DRDC as to how OpenSim or similar vWorld technology could be used to support activities such as concept development, collaborative design review, and experimentation for operations rooms in naval platforms.

[2] Summarized from Wikipedia: http://en.wikipedia.org/wiki/Virtual_world

1.3 Scope of Literature Survey

Following submission of a draft report (Version 01), the objectives and scope of the literature survey was discussed between DRDC and CAE. The scope of the literature survey was revised and requested by DRDC to be as follows:

- Convergent and divergent trends;
- Active user community and applications;
- The use of OpenSIM in support of system development for: Navy operations, Navy training, other military operations and training, real-time defence and security (e.g., emergency operations) or other real-time, operational, complex, high-risk environments;
- How OpenSIM can be linked to other analysis tools; and,
- How OpenSIM has been linked to other applications (CAE, 2013b).

1.4 This Document

The structure of this document is described as follows:

- **Section 1: Introduction.** Presents an overview of the contract, objectives, and scope of this report;
- **Section 2: Method.** Presents the method used to conduct the literature survey including the approved keywords by DRDC and documents reviewed by CAE for both the original and revised scope of work;
- **Section 3: Results.** Presents the results of the literature survey including examples of vWorlds platforms, an overview of the documents reviewed, and known users and applications of the OpenSIM platform in the areas of interest to DRDC;
- **Section 4: Discussion.** Presents a discussion of the common issues and requirements of using the OpenSIM platform for systems development and training. Practical solutions are then proposed to address these issues and requirements;
- **Section 5: Conclusions & Recommendations.** Presents concluding remarks and recommendations for follow on work;
- **Section 6: References.** Presents a list of cited references;
- **Section 7: List of Acronyms.** Identifies the acronyms and abbreviations used throughout this document; and,
- **Appendix A.1: Search Results (Original Scope).** Presents the search results for the original scope of work.

2 METHOD

This section documents the method that was used to conduct the literature survey. The following approach was taken:

- Prior to conducting the search, the CAE Team collaborated with the Scientific Authority (SA) to agree upon the process, the dimensions (i.e., keywords and databases) and responsibilities. The SA provided direction regarding key literature to be reviewed;
- Conducted the search of publicly accessible databases using approved keywords;
- The search of publicly accessible databases using the keyword combinations led to large numbers of potentially relevant literature. Accordingly, criteria was developed and used to reduce the number of relevant findings in the literature survey; and,
- Approved references were subsequently reviewed.

2.1 Keywords

The following keywords were validated with the SA and used to conduct the literature search:

- Applications
- Army
- Challenges
- Collaboration
- Command and Control (C2)
- Command center
- Command centre
- Concept development
- Control room
- Center
- Centre
- Defence
- Defense
- Design review
- Education
- Experimentation
- Human Centered Design
- Human Factors
- Human Systems Integration (HSI)
- Joint Interagency Multi-National and Public (JIMP)
- Joint
- Lessons Learned
- Military
- Modeling
- Modelling
- Multi-National
- Navy
- Open Simulator
- OpenSim
- Operations (Ops) Center
- Operations (Ops) Centre
- Operations
- Ops room
- Requirements Analysis
- Research
- Second Life
- Serious Games
- Simulation
- Success
- System analysis
- System design
- System evaluation
- Team decision making
- Teamwork
- Training
- Unity
- Use cases
- Virtual Worlds

2.2 Documents Approved for Review

This section presents the documents that were approved by the SA for review by CAE. The complete search results are presented in Appendix A.1.

A total of 75 items were identified for potential review and each abstract was evaluated by the SA, identifying the following 29 documents as high priority based on their relevance to supporting concept development, collaborative design review and experimentation for operations rooms in naval platforms:

1. Aguiar, S., & Monte, P. (2011) *Virtual worlds for C2 design, analysis, and experimentation*. Paper presented at the 16th ICCRTS conference, Quebec. Naval Undersea Warfare Center, Newport, RI (p.8 plus presentation slide deck). Retrieved from: http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA547157

2. Boldyreff, C., Dastbaz, M., Liu, H., & Arafa, Y. (2011). Engineering Advanced Training Environment for Crisis Management: The Pandora Project. *Proceedings of Advances in Computing and Technology Conference, USA*, pp. 125-131. Retrieved from: http://pandora.xlab.si/media/uploads/files/PandoraACT11.pdf

3. Carvalho, M. M., & Ford, R. (2012). NextVC2: A next generation virtual world command and control. *Proceedings of the Military Communications Conference, USA*, pp. 1-6. Retrieved from: http://www.researchgate.net/publication/233401833_NextVC2_-_A_Next_Generation_Virtual_World_Command_and_Control/file/d912f50f19f20c9f24.pdf

4. Champsas, I., Leftheris, I., Tsiatsos, T., Terzidou, T., & Mavridis, A. (2012). OpenGames: A Framework for Implementing 3D Collaborative Educational Games in OpenSim. *Proceedings of the 6th European Conference on Games Based Learning, Academic Conferences Limited*, p. 82.

5. Cohen, D., Sevdalis, N., Patel, V., Taylor, M., Lee, H., Vokes, M., & Darzi, A. (2013). *Tactical and operational response to major incidents: feasibility and reliability of skills assessment using novel virtual environments*. Resuscitation.

6. Dafli, E. L., Vegoudakis, K. I., Pappas, C., & Bamidis, P. D. (2009). Re-use and exchange of an Opensim platform based learning environment among different medical specialties for clinical scenarios. *Proceedings of Information Technology and Applications in Biomedicine, 9th International Conference*, pp. 1-5.

7. Delp., S. L., Anderson, F. C., Arnold, A. S., Loan, P., Habib, A., John, C. T., Guendelman, E. and Thelen, D. G. (2007). OpenSim: Open-Source Software to Create and Analyze Dynamic Simulations of Movement. *IEEE Transactions on Biomedical Engineering, 54 (11)*, pp. 1940-1950.

8. Diener, S., Windsor, J., & Bodily, D. (2009). *Design and Development of Medical Simulations in Second Life and OpenSim*. Educause, Australasia.

9. Gardner, M., & Horan, B. (2011). +SPACES: Serious Games for Role-Playing Government Policies. *Proceedings of Researching Learning in Immersive Virtual Environments, The Open University, Milton Keynes, UK*, pp. 102-112. Retrieved from:

http://repository.essex.ac.uk/3849/1/%2BSPACES%20Serious%20Games%20for%20Role-Playing%20Government%20Policies.pdf

10. Garrett, R. B., Tolk, A., & Bacon, T. J. (2009). Exploring effective methods for modelling a comprehensive approach to Political, Military, Economic, Social, Information, and Infrastructure (PMESII)/Human, Cultural, Social, and Behavorial (HSCB) Community of Interest (CoI). *Proceedings of the Winter Simulation Conference, IEEE*, pp. 2860-2866.

11. Hudson, K., & Nissen, M. E. (2010). *Command & Control in Virtual Environments: Designing a Virtual Environment for Experimentation*. Naval postgraduate school, Montery, CA.

12. Koutsabasis, P., Vosinakis, S., Malisova, K., and Paparounas, N. (2011). *On the value of virtual worlds for collaborative design*. Retrieved from: http://extev.syros.aegean.gr/papers/J55.pdf

13. Krause, D., Strickler, M., & Clark-Casey, J. (2010). Utilizing Open Source Virtual World Platforms for Business and Serious Games. *Journal of Competence Management for Open Innovation: Tools and It Support to Unlock the Innovation Potential Beyond Company Boundaries, 30*, p. 299.

14. Liu, H. and Duffy, A. M. (2012). Enabling behaviour reuse in development of virtual environment applications. *Proceedings of the 2012 Winter Simulation Conference*. Retrieved from: http://www.simulation.kiev.ua/doc%5Cconference%5Cwsc%5C2012%5Cinv186.pdf

15. Liu, H., Arafa, Y., Boldyreff, C., & Dastbaz, M. (2011) Cost-effective virtual world development for serious games. *Proceedings of Games Innovation Conference, IEEE*, pp. 48-51.

16. Mavridis, A., Konstantinidis, A., & Tsiatsos, T. (2012). A Comparison of 3D Collaborative Virtual Learning Environments: OpenSim vs. Second Life. *International Journal of e-Collaboration (IJeC), 8(4)*, pp. 8-21. Retrieved from: http://www.fardinpour.info/system/files/myfiles/Mavridis_etc%282012%29ComparisonVLE_OpenSim_SecondLife.pdf

17. Michel, M. K., Helmick, N. P., & Mayron, L. M. (2011). Cognitive cyber situational awareness using virtual worlds. *Proceedings of Cognitive Methods in Situation Awareness and Decision Support (CogSIMA), First International Multi-Disciplinary Conference, IEEE*, pp. 179-182.

18. Miehling, J., Krüger, D., & Wartzack, S. (2013). Simulation in Human-Centered Design–Past, Present and Tomorrow. *In Smart Product Engineering* (pp. 643-652). Springer Berlin Heidelberg. Retrieved from: http://link.springer.com/chapter/10.1007/978-3-642-30817-8_63

19. Muller, D. and Schaf, F. M. (2009). A low cost learning environment for collaborative engineering. Retrieved from: http://coral.ufsm.br/eduworlds/public/papers/schaf_rev2009.pdf

20. Mumme, C., Olivier, H., & Pinkwart, N. (2008). A Framework for Interaction Analysis and Feedback in Collaborative Virtual Worlds. *Proceedings of the 14th International Conference on Concurrent Enterprising*, pp. 143-150. Retrieved from: http://www.ve-forum.org/projects/408/ICE%202008/Collaborative%20Systems/016.3%20-

%20CWE23%20Mumme_Olivier_Pinkwart_Framework_for_CVE_analysis%20_final%20SS6_2.pdf

21. Nakasone, A., Prendinger, H., Miska, M., Lindner, M., Horiguchi, R., & Kuwahara, M. (2011). Openenergysim: A 3d internet based experimental framework for integrating traffic simulation and multi-user immersive driving. *Proceedings of the 4th International ICST Conference on Simulation Tools and Techniques*, pp. 490-498. Retrieved from: http://i-transportlab.jp/publications/papers/pdf/SimWorks2011_Helmut.pdf

22. Onyesolu, M. (2009). Virtual Reality Laboratories: An ideal solution to the problems facing laboratory setup and management. *Proceedings of the World Congress on Engineering and computer science*. Retrieved from: http://www.iaeng.org/publication/WCECS2009/WCECS2009_pp291-295.pdf

23. Pierera, I., Allision, C., and Miller, A. (2010). A Use Case Analysis for Learning in 3D MUVE: A Model Based on Key eLearning Activities. Retrieved from: http://www.icvl.eu/2010/disc/icvl/documente/pdf/met/ICVL_ModelsAndMethodologies_paper15.pdf

24. Scacchi, W., Brown, C., & Nies, K. (2012, June). Exploring the potential of computer games for decentralized command and control. *Proceedings of the 17th International Command & Control Research & Technology Symposium (ICCRTS).* Retrieved from: http://dodccrp.org/events/17th_iccrts_2012/post_conference/papers/104.pdf

25. Intel Corporation (2009). *Science Sim: A virtual environment for collaborative visualization and experimentation*. White Paper. Retrieved from: http://software.intel.com/sites/default/files/m/d/4/1/d/8/ScienceSimWP_CCEFinal.pdf

26. von Kapri, A., Ullrich, S., Brandherm, B., & Prendinger, H. (2009). Global lab: an interaction, simulation, and experimentation platform based on" second life" and" opensimulator". *Proceedings of the Pacific-Rim Symposium on Image and Video Technology*. Retrieved from: http://anettevonkapri.org/wp-content/uploads/2012/12/KUB+2009.pdf

27. Wagner, G. (2010). Model-driven engineering of Second-Life-style simulations. *Proceedings of the Winter Simulation Conference, IEEE*, pp. 791-798.

28. Watte, J. (2009). Virtual world interoperability: let use cases drive design. Journal of Virtual Worlds Research, 2(3), pp. 1-13. Retrieved from: http://jvwr-ojs-utexas.tdl.org/jvwr/index.php/jvwr/article/download/727/526

29. Winkler, S. E. (2010). Licensing Considerations for OpenSim-Based Virtual Worlds. Retrieved from: http://journals.tdl.org/jvwr/index.php/jvwr/article/download/871/636

The list of references to review was further reduced to focus on the most relevant documents and match the level of effort available in the contract. The following 10 documents were reviewed in further detail to address the DRDC interests outlined in Section 1.3:

1. Aguiar, S., & Monte, P. (2011) *Virtual worlds for C2 design, analysis, and experimentation*. Paper presented at the 16th ICCRTS conference, Quebec. Naval Undersea Warfare Center,

Newport, RI (p.8 plus presentation slide deck). Retrieved from: http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA547157

2. Allen, P.D. & Demcahk, C. C. (2011). Applied virtual environments: applications of virtual environments to government, military, and Business Organizations. *Journal of Virtual Worlds Research, 4(1)*, pp. 1-27.

3. Carvalho, M. M., & Ford, R. (2012). NextVC2: A next generation virtual world command and control. *Proceedings of the Military Communications Conference, USA*, pp. 1-6. Retrieved from: http://www.researchgate.net/publication/233401833_NextVC2_-_A_Next_Generation_Virtual_World_Command_and_Control/file/d912f50f19f20c9f24.pdf

4. Hsu, E. B., Li, Y., Bayram, J. D., Levinson, D., Yang, S., & Monahan, C. (2013). *State of Virtual Reality Based Disaster Preparedness and Response Training*. PLoS currents, 5. Retrieved from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3644293/

5. Maxwell, D. (2009). *Application of Virtual World Technologies to Undersea Warfare Learning*. Naval Undersea Warfare Center Division, Newport, RI. Retrieved from: http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA530269

6. Maxwell, D., Aguiar, S., Monte, P., & Nolan, D. (2011). Two Navy Virtual World Collaboration Applications: Rapid Prototyping and Concept of Operations Experimentation. *Journal of Virtual Worlds Research, 4(2)*. Retrieved from: http://jvwr-ojs-utexas.tdl.org/jvwr/index.php/jvwr/article/download/2113/5551

7. Scacchi, W., Brown, C., & Nies, K. (2012, June). Exploring the potential of computer games for decentralized command and control. *Proceedings of the 17th International Command & Control Research & Technology Symposium (ICCRTS).* Retrieved from: http://dodccrp.org/events/17th_iccrts_2012/post_conference/papers/104.pdf

8. Smith, R. (2011) Creating a killer app for the department of defence. *Journal of Virtual Worlds Research, 4(1)*, pp. 1-5.

9. Tate, A., Dalton, J., & Potter, S. (2009). I-Room: a Virtual Space for Emergency Response for the Multinational Planning Augmentation Team. *Proceedings of the Fifth International Conference on Knowledge Systems for Coalition Operations (KSCO-2009) (Vol. 31), Chilworth Manor, Southampton, UK, March*, pp. 1-5.

10. von Kapri, A., Ullrich, S., Brandherm, B., & Prendinger, H. (2009). Global lab: an interaction, simulation, and experimentation platform based on” second life” and” opensimulator”. *Proceedings of the Pacific-Rim Symposium on Image and Video Technology*. Retrieved from: http://anettevonkapri.org/wp-content/uploads/2012/12/KUB+2009.pdf

3 RESULTS

This section presents the results of the literature survey including examples of vWorld platforms, identified users and applications of the OpenSim platform in the areas of interest to DRDC.

3.1 vWorld Platforms

Examples of vWorld platforms extracted from the surveyed literature are presented in this section. Identified users and applications of the OpenSim platform from the defence and security realm are noted accordingly in Section 3.2. Most of the simulation environments allow the user to assemble predefined objects in various ways. Content creation is done outside of the vWorlds using modelling tools (e.g. AutoCAD, SketchUp, and Autodesk Maya) that support common industry object formats (e.g. Collaborative Design Activity, COLLADA).

3.1.1 Second Life

Second Life (SL, http://secondlife.com) is a commercial, persistent, 3-Dimensional (3D), virtual world that provides simple modelling tools and a scripting language for the creation of interactive objects and the alteration of the worlds' physics. In SL, educators can create interactive activities for the support of experiential, project-based and community service-based learning (Bedford, Birkedal, Erhard, Graff, & Hempel, 2006). In SL, chatting with others and navigating the vWorld is without charge, but creating permanent objects and buildings requires the acquisition of virtual land from the developers or from other users.

3.1.2 OpenSIM

OpenSIM (http://opensimulator.org) is an open source server platform for hosting vWorlds. Its main feature is the compatibility with the SL client using the SL protocol for client-to-server communication. The modelling tools and the scripting language are similar to those used in SL (Gardner & Horan, 2011; Mavridis, Konstantinidis, & Tsiatsos, 2012). Creating objects and importing things (e.g., textures) in OpenSIM is without charge. Every user has private land on which they can create their own environment. Gaining access to an OpenSIM public environment can only be done once the administrator of that particular OpenSIM virtual world grants the user permission to access that world (Pierera, Allison, & Miller, 2010); however, the OpenSIM software may be downloaded and used free of charge on private networks.

3.1.3 VBS2 / VBS3

Virtual Battlespace 3 (VBS3; http://products.bisimulations.com/), and its predecessor VBS2, is a serious-game-based virtual environment, providing terrain and scenario editors. VBS2 has focused primarily on land combat although other domains are possible. VBS3 provides a development user interface to modify and extend the capability inherent in the product. Note that the persistence capability inherent in many vWorld products is missing in VBS3. DND has approved VBS2 for use on the DWAN and it is currently being applied by the Director Land Synthetic Environments (DLSE) Canadian Forces Base (CFB) Kingston.

3.1.4 Active Worlds

In Active Worlds (http://www.activeworlds.com), users communicate with others and create their own personal 3D virtual space. The educational capabilities of Active Worlds have been explored by a learning community known as Active Worlds Educational Universe (AWEDU) that provides educators, students, educational institutions and individual programs with the Active Worlds technology (Dalfi, Vegoudakis, Pappas, & Bamidis, 2009). Through Active Worlds, educators can assess new ideas, learning theories and teaching. Institutions already using Active Worlds include the Boston Museum of Science, the San Jose Tech Museum of Innovation, the National Aeronautics and Space Administration (NASA) Ames Research Laboratory (Mavridis, Konstantinidis, & Tsiatsos, 2012).

3.1.5 Croquet

Croquet (http://opencroquet.org) is an open source cross platform 3D environment designed for multi-user interaction and simulation (McCahill, 2004). Written in Squeak, an object and class based, reflective Smalltalk implementation, Croquet is a combination of open source software and peer-to-peer network architecture providing an infrastructure for synchronous, real-time problem solving within shared simulations (Kadobayashi, Lombardi, McCahill, Stearns, Tanaka, & Kay, 2005; Watte, 2009; Mavridis, Konstantinidis, & Tsiatsos, 2012).

3.1.6 OLIVE

Science Applications International Corporation's (SAIC) On-Line Interactive Virtual Environment (OLIVE[3]) 3.0 is a cloud based platform that runs on Virtual Machine based servers that are always-on. The functionality of OLIVE allows for basic communication and person-to-person interaction as in both SL and Teleplace.

3.1.7 Open Cobalt Alpha

Open Cobalt Alpha (http://www.opencobalt.org/) is an open source platform that uses 3D multimedia wiki technology that allows the user to create collaborative and hyperlinked multi-user virtual workspaces on major software operating systems. Cobalt Alpha vWorlds may be hyperlinked via 3D portals to form a distributed network of interconnected collaboration spaces using a peer-based messaging protocol that reduces demands on server infrastructures (Gardner & Horan, 2011). It supports integrated web browsing, voice chat, text chat as well as access to remote desktop applications and services.

3.1.8 OpenEnergySim

OpenEnergySim is an integrative vWorlds based platform that combines traffic simulation and user driving experience with the goal of providing traffic engineers with a simulation tool for exploring and testing Intelligent Transportation System (ITS) strategies (Nakosone et al., 2011).

[3] Highlights of OLIVE 3.0. Retrieved on 03 April 2014 from: https://www.leidos.com/sites/default/files/imported/products/simulation/olive/download/olive-highlights.pdf

3.1.9 Open Wonderland

Open Wonderland (http://openwonderland.org) is a Java-based open-source toolkit for creating collaborative 3D vWorlds. Basic features allow users to interface with external applications (e.g., Open Office, Firefox, and Skype) visualized as 2D windows in the vWorld and to add audio/video recordings or streaming audio/video to in-world objects (Koutsabasis, Vosinakis, Malisova, & Paparounas, 2011). The Open Wonderland Foundation operates two community servers that are intended for user created vWorlds for demonstration purposes only. The servers are reset on a regular basis, so individual work cannot be saved on these servers. Open Wonderland also offers security and authentication features for user groups (Mavridis, Konstantinidis, & Tsiatsos, 2012). Instructions for connecting to a community server can be found on the Open Wonderland website.

3.1.10 Pivote

Pivote (http://www.pivote.info) is an open source virtual authoring system for vWorlds orignially developed for training medical professionals in higher education. All the structure and information content of an exercise is stored on the web, not in the vWorld, permitting development of courseware independent of the vWorld to facilitate reuse of models and courseware across a number of applications (Gardner & Horan, 2011; Mavridis, Konstantinidis, & Tsiatsos, 2012).

3.1.11 Teleplace

Teleplace (http://telexlr8.wordpress.com/openqwaq/teleplace/) is a 3D videoconferencing environment that offers basic functionality to support telework, online meetings, group collaboration and e-learning. The spaces within Teleplace are interior only spaces, with no access to natural landscapes. Hudson and Nissen (2010) state that Teleplace does not offer any JavaScript functionality; nor does it provide the source code. The authors also state that Python scripting language is supported by Teleplace, which would allow developers to recreate the scripted content. However, significant reworking of these models may be required to make even minor changes to the experimental spaces.

3.2 Overview of Documents

This section provides a brief overview of the documents reviewed in accordance to the revised scope of objectives. Additional details regarding the applications and user community of OpenSIM are presented in Section 3.3. Issues and requirements for systems development and training applications are presented in Section 4.1 and Section 4.2, respectively.

3.2.1 Aguiar & Monte (2011)

This paper describes how vWorlds can enhance the design process for submarine C2 systems by involving fleet personnel in design and experimentation. The US Navy has investigated and applied multiple applications of vWorlds technology to the undersea warfare (USW) domain for Anti-Submarine Warfare (ASW) and mine warfare. One area of application that is being supported is C2 collaborative engineering and concept of operation experiments (COOPEXs). Collaborative engineering is a systematic approach to the integrated, concurrent design of C2 systems ranging from a single system (e.g., ship navigation) to a full, multisystem Command

Center. The COOPEX involves experimenting with proposed C2 concepts in a vWorld, before committing the operational fleet to new equipment, operating procedures, or manning concepts. The authors describe how vWorlds can offer an environment for multidisciplinary groups of stakeholders (i.e. Integrated Product Teams, IPT) to effectively design prototype C2 systems in real time while utilizing video, voice, chat and real-time modelling tools for modifying the virtual environment. For example, in October 2010 a program under the Office of Naval Research held a week-long arrangement studies workshop in Groton, CT, during which submarine crews, with the aid of C2 subject matter experts and cognitive scientists, generated 10 separate Command and Control Center (CACC) arrangements in a vWorld in real-time. These prototypes were then used to analyze pre-recorded C2 events to visually expose each architecture component (e.g. workspace, human communications, Human-System Interface (HSI), team structure, work flow, task flow, automation or training) as it affects a specific mission scenario. In addition, vWorlds allowed these virtual prototypes to be evaluated by fleet personnel immersed into the environment with enough fidelity to allow operator performance prediction.

3.2.2 Allen & Demchak (2011)

This paper presents a set of vWorlds features and their use in a wide range of application areas involving training, operational, and rehearsal objectives.

The authors propose four main advantages of vWorlds compared with conventional design methods, although the emphasis on the need for a high degree of realism is contentious and unsupported by the scientific literature in general (Lintern et al., 1997; Salas et al., 2009; Smallman & St.John, 2005). The four noted advantages are:

- Provide as close of a representation of reality as possible;

- Allow selected laws of physics to be violated. Enhanced reality involves providing additional information to the participant that would not be available in the real world, but facilitates the achievement of the application's objectives. For instance, the ability to see the layout and functioning of a ship's sub-systems may be essential to achieving the training objectives for the maintenance of those systems;

- Provide different levels of resolution to demonstrate how different echelons of management view the same situation. For example, a ship will have a detailed view of its area of responsibility but the Maritime Component Command element ashore will have a view of the ship that is much reduced in detail. The ability not only to see these different echelons and perceptions but also to be able to quickly shift from one to the next, may be advantageous to the participants depending on the application areas; and,

- Provide perceived realities based on the perceptions of various participants. Camera options can permit users in vWorlds to represent how each friendly, enemy, neutral or wavering entity views each other's situation. This ability is useful for training and for purposes such as wargaming where Blue forces take the role of the adversary to identify weaknesses in potential courses of action. Seeing what you can see and seeing what you think others can see can be essential to planning and other Information Operations.

3.2.3 Carvalho & Ford (2012)

This paper presents a vWorld-based approach to C2 for joint operations where coalition partners participate in a common vWorld C2 environment (e.g., virtual ops room, bridge, forward operating base, and vehicle on patrol). A prototype of the proposed capability was implemented and demonstrated as an extension to OpenSIM. The authors describe the approach but provide very limited details of the prototype implementation and preliminary capability demonstrations.

Much of the paper is dedicated to discussing the differential presentation of information to users with varying security restrictions. A common approach for information protection is to create a physical environment whereby multiple vWorlds exist and information can be shared, tightly constraining access to such environments only to authorized parties. They cite a number of studies of C2 systems in virtual reality settings but provide no summary of the findings; they note that the focus has been on the user interaction with the simulation and collaboration capabilities of the virtual environments but provide no evidence from the studies to suggest that the vWorlds were valid for those applications.

The authors believe that being able to selectively and automatically control the release of information to users is critical to widespread adoption of vWorlds for C2 training and use. They approach the “context-dependent information release” problem by controlling access to information through administrative computer policies that seem to hide the details, in effect, preventing the unauthorized user from knowing what they don’t know.

The authors recommend performing a requirements analysis for selective access to sensitive resources or information in vWorld applications. Much of this information should be represented in policies, doctrine, standard operating procedures, tactics, techniques and procedures, and regulatory constraints, but it is often up to humans in the environment to enforce such constraints during ad hoc meetings and discussions which may be impractical in time critical settings.

3.2.4 Hsu et al. (2013)

This paper is a literature review that lists applications of vWorld-based training for disaster preparedness and response in the United States by a variety of government departments and agencies including the U.S. Department of Homeland Security (DHS), the Centers for Disease Control and Prevention (CDC) as well as academic institutions. The authors are interested in determining whether virtual reality based simulation technologies (of which vWorlds are but one class of simulation approaches) can augment or improve on more traditional approaches to training, particularly for events that involve sizable participants that must interact both with each other and with the environment. They note that a number of academic institutions have evaluated virtual reality training effectiveness in some applications, but they cite no publications. They do go on to cite several government and academic studies of virtual reality training simulations, but they do not summarize the findings from these studies.

They note, however, that there are some caveats to vWorld training including lack of support from training managers, presumably due to the lack of evidence that the technology is effective, and they cite the need for validation studies to support cost-effectiveness arguments. They also note that these applications are still simulations and that user interaction with the simulation can differ markedly from the real life counterpart, leading to additional training requirements simply

to use the training device and frequently not providing proprioceptive or tactile feedback thought to be necessary in some applications.

The paper includes a list of academic programmes and commercial ventures developing virtual reality based environments aimed at disaster and medical preparedness training. Unfortunately, they focus on the functionality of these instantiations rather than what they are effective at accomplishing, making no statement on whether the applications are valid or if validation studies have been conducted.

Examples of vWorld applications noted in this paper include:

- The use of a virtual reality patient simulation system for teaching emergency response skills to U.S. Navy medical providers (Freeman et al., 2001). Although this reference pre-dates OpenSIM, it may be an example of a vWorld domain that could be explored in OpenSIM;
- Immersive simulation for training first responders for mass casualty incidents (Wilkerson et al., 2008);
- Simulation for team training and assessment using virtual worlds (Becerra-Fernandez et al., 2008);
- Virtual simulation as an instructional method for nursing students was demonstrated to reinforce learning and improve learning retention over time (Farr et al., 2013);
- New York City Office of Emergency Management (OEM) is using the Advanced Disaster Management Simulator (ADMS[4]) training system developed by Environmental Tectonics Corporation that employs artificial intelligence. The system focuses on command element simulation and allows trainees to navigate through the virtual replica city by means of a joystick. Trainees can communicate emergency response needs through a facilitator who guides them through decision points and objectives; and,
- The Los Angeles Police Department is using the commercially available Hydra Simulation Training System[5] to foster disaster-based training for its incident command officers. This system can be interlinked with other emergency operation centers around the world. With a variety of newscasts, briefings and other simulated real-time information, Hydra features immersive simulation training with video feeds that monitor decision-making processes.

3.2.5 Maxwell et al. (2011)

This paper describes the Naval Undersea Warfare Center (NUWC) work with vWorlds for applications including rapid prototyping and design activities, virtual concept of operations exercises and training Target Motion Analysis (TMA). They note that traditional design evaluation methods involving scale models and full size mock ups are useful but can be expensive and they are typically non-functional. NUWC is exploring the use of vWorlds to provide a virtual mock up environment to simulate submarine work spaces that attempt to

[4] Available at http://www.trainingfordisastermanagement.com. Accessed on 07 January 2014.
[5] Hydra System Simulation Training. Available at: http://www.govtech.com/public-safety/Los-Angeles-Police-Hydra-Simulation-Training.html. Accessed on 07 January 2014.

constrain and enable the user similar to the real (or envisioned) submarine to assess design and information flow. They note that a balance must be struck between security and connectivity to allow remote users to participate in the design evaluation, but also note that there are several secure networking technologies available. They also recognize that the vWorld environment needs to support a number of human factors elements such as natural communications, sight lines and physical restrictions if the environment is to be used to assess usability.

The requirements and challenges for vWorld selection of these applications are provided. Modification of the vWorld contents should be possible while the simulation is running so that designs can evolve effectively. They also note that users will come from a wide range of backgrounds so that the user interface should be designed for both the naïve and expert user. The authors describe the design, test and evaluation of a Command and Control Center (CACC) inside a vWorld simulation of operations exercises. By transforming physical mock ups into virtual objects, the costs of rapid prototyping are demonstrated to be drastically reduced. They noted that, at the time, Second Life was the only vWorld environment that had a user interface and model modification capability adequate to meet their rapid prototyping requirements, although other environments actually provided better support for importing wire-mesh models. A hypothetical Virginia class attack centre was created in Second Life with sufficient detail to allow users to perform certain procedures, interacting with consoles and viewing information on screens, in order to assess information flow, although no assessment of the effectiveness was reported.

The authors explored vWorld technologies as a replacement for Concept of Operations Exercise (COOPEX) that required different capabilities from rapid prototyping (although specific details beyond integrating video feeds were not reported) and determined that the Teleplace environment was the most capable to create their virtual submarine environment. They conducted a study in the Teleplace virtual submarine as well as with real equipment in a physical environment, using both a naïve and an expert team of submariners conducting a target motion analysis task. Subjective observations and subject feedback suggested that both simulated and physical environments were equally effective, but there were insufficient performance data to make firm conclusions. The authors noted that the vWorld developer interface was awkward and that “camera” control was important to collaboration (user controlled sight lines.) A major hurdle was the level of detail of imported models, many of which had to be simplified in order to obtain adequate simulation performance.

3.2.6 Maxwell (2009)

This is a Microsoft PowerPoint presentation that is related to the work of Maxwell et al. (2011). The presentation is an information brief that describes the characteristics of vWorlds technologies and NUWC mission objectives with respect to collaboration and innovation in FY08 (investigation of various vWorlds platforms) and FY09 (experimentation to effectively apply vWorlds in support of undersea warfare mission areas). The presentation notes that NUWC is organizing a coordinated military coalition presence (i.e., Army, Navy, Air Force, Marines and others) into Second Life. Project Bluejacket is presented as an exploration of a vWorld technology to teach basic submarine tactical skills such as TMA.

3.2.7 Scacchi, Brown & Nies (2012)

This report describes results from a one year long research study investigating how vWorlds concepts, techniques and tools can be used to create an online environment that supports experiments in Decentralized Command and Control (DCC). The objective is to allow remote users to work or train in virtual command and control centres as if they were co-located in a physical centre. The intent is to follow the government wide initiative to exploit open source software wherever it is cost effective. Their efforts depart from current C2 practice but seek to advance scientific and technical knowledge of how vWorlds might be leveraged to support future C2 practice.

The authors describe the development of a decentralized prototype computer game and virtual world collectively referred to as the DECENT system. The system is implemented in OpenSIM and allows authors to rapidly create a functional C2 vWorld analog, i.e., a simulation of a C2 environment (e.g., virtual ops room, bridge, forward operating base, and vehicle on patrol) that works similarly to the real C2 environment, and populate it with users for concept prototyping, testing and experimentation.

The authors began the development of physical places in vWorlds by first inspecting the components and layouts of real C2 structures from images of C2 facilities (e.g., Hanscom Air Force Base) in order to identify elements to replicate in the vWorlds. The authors replicated elements common to C2 facilities including shared resources such as large screen displays and tabletop surfaces used to display streaming video, as well as static images and a mission planning counterterrorism training game. Other elements replicated in the vWorld include private resources such as operator workstations and other mission resources.

The authors state that research is needed to evaluate and compare the validity of alternative vWorlds and game technologies, and the affordances they provide, within a controlled experimental environment. Replicating real C2 components in a vWorld provides the basis for the systematic investigation and experimentation of C2 related issues. They cite experiments to investigate the efficacy of team organization, team dynamics, and training outcomes when done in the real world in comparison to a virtual world (e.g., Bergin et al., 2010; Hudson & Nissen, 2010, 2011; Wynn, Ruddy, & Nissen, 2010), although summaries of these efforts are not provided.

The authors note that integrating DECENT with other currently existing military OpenSIM projects (e.g., US Army Military Open Simulator Enterprise Strategy, MOSES, 2012; NUWC virtual campus, Aguiar & Monte, 2011) can be done by adding a new region and importing the DECENT assets, or establishing a hypergrid connection, or federation between the two virtual worlds.

Overall, the authors recommend using OpenSIM for vWorlds development because it was easy to use and allowed them to quickly develop the DECENT system. They provide further reasons for adopting OpenSIM in comparison to SL along the dimensions of cost, users, stability, asset ownership, and scripting. Based on these dimensions, OpenSIM is free of charge, has access to smaller groups of existing users, tends to have much more stable connectivity and voice-chat, offers controlled access and ownership of servers and supports the Linden Scripting Language and provides an Application Programming Interface (API) that additionally allows the developer to extend OpenSIM capabilities using C++, Matlab or Python.

3.2.8 Smith (2011)

This article explores the slow adoption of vWorlds by organizations within the US Department of Defense and suggests some features that might make vWorlds more appealing for military training and game-based applications. Smith notes that for vWorlds to be adopted more broadly by the Department of Defense, vWorlds must provide additional capabilities (or at least more convenient instantiations of existing capabilities) that go beyond mere collaboration, because many collaborative tools are already in use. Few if any vWorlds have made the effort to include the military behaviours demonstrated in first person shooter (FPS) virtual environments. Smith goes on to state that developing a wide variety of capabilities is beyond any single company; a task that is distinct from the creation and operation of a vWorld infrastructure, although it seems a strange observation when companies can produce FPS with such capabilities. Nevertheless, providing tools to allow developers to create and share models seems to be a natural alternative to a single company endeavour.

Smith makes an excellent point, one that is commonly overlooked in the current climate to adopt all things technological: *"If your organization were given (a vWorld), what could you use it for out of the box?"* Unfortunately, this misses the mark somewhat and might better read: "What should you use a vWorld for?" In other words, where would it be cost effective compared with alternative approaches?

3.2.9 Tate, Dalton, & Potter (2009)

This paper describes the characteristics of an I-Room or "intelligent room" that serves as a knowledge aid to support collaborative meetings. I-Room was developed to aid sense-making[6] about the current situation during planning, option analysis, and decision-making. I-Rooms are being created on a number of virtual world environments with an emphasis on sharing concepts and systems support. They are also being applied to a range of collaborative tasks such as homeland security, UAV mission monitoring, product design and review meetings, scientific project regular reviews and team training. The authors describe the concept of an Emergency Response Virtual Collaboration Centre, realized in SL and OpenSIM, within which it is possible to set up and maintain a persistent set of information assets (e.g. wall posters, maps, etc.) and dynamically loaded content (such as imagery, movies, web page contents, etc.) in an area that is shared by the participants. The I-Room is meant to provide a generic technology basis for a wide range of potential collaborative applications (see Section 4.1.2). The authors cite an example of a collaborative application, i.e. the "I-X Process Panel", implemented in OpenSIM that serves as a form of "to-do" list.

3.2.10 von Kapri et al. (2009)

This paper describes a vWorld called Global Lab. The motivation behind the work is to provide a framework with strong support for collaboration in vWorlds for research purposes. The Global Lab platform contains multimodal presentation and interaction communication, but goes beyond communication to demonstrate development and inclusion of physics-based models of objects in the environment. Two example applications are presented that demonstrate the capabilities of Global Lab for simulation-based experimentation with sensor-based systems. For example, an

[6] Sense-making is the iterative process of gathering information, interpreting information, and developing mental models (conceptualizations or beliefs) in order to make rational decisions.

animation authoring tool for virtual bots is described using an XML-based scripting language called Multi-modal Presentation Markup Language (MPML3D) that is used to control the speech output and non-verbal behavior (e.g. gestures and facial expressions) of bots (Artificial Intelligence controlled agents in simulations.) The MPML3D scripting language can be integrated with OpenSIM and SL vWorlds to provide agent representation for these domains. von Kapri et al. note that verbal communication in vWorlds is usually accomplished through a chat interface that displays text on the screen, although bots could, in principle, use a speech production interface or recorded speech to communicate with virtual users.

3.3 OpenSIM User Community and Applications

This section presents the user community of OpenSIM in the application domains of interest to DRDC including: Navy operations, Navy training, other military operations and training, real-time defence and security environment (e.g., emergency operations), and other real-time operational environments. Also, the manner that OpenSIM is used in support of systems development is presented (e.g., rapid prototyping, concept development, and experimentation). Example applications are described and references are provided in the Table 3-1.

Table 3-1: OpenSIM User Community and Applications

OpenSIM User Community	Application Domains	Example Applications
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.	Navy operations, C2 design and experimentation	Several US Navy programs are tasked with investigating various aspects of future submarine C2 design. NUWC is planning to conduct experiments to improve the current Virginia Class submarine attack center design as well as provide design inputs for the Ohio Replacement Program (ORP) in order to achieve better performance across a greater variety of mission areas for their submarine fleet.
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.	Navy Training	Project Bluejacket: A scenario simulation to explore the use of vWorlds technology to teach basic submarine tactical skills such as Target Motion Analysis (TMA), contact management, and weapon presenting.
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.	Navy Training	Immersive Towed Array (Aguiar & Monte, 2011).
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.	Navy Training	Immersive sound propagation (Aguiar & Monte, 2011).
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.	Navy Training	Enterprise Resource Planning (ERP) training simulation (Aguiar & Monte, 2011).
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.	Navy operations and Analysis	C2 information flow playback: vWorlds used to visualize information flow within a C2 space by showing visual, audio, control, and electronic transmission paths.(Aguiar & Monte, 2011)
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas	Navy operations and analysis	Theater C2 Modelling and Simulation (Aguiar & Monte, 2011).

OpenSIM User Community	Application Domains	Example Applications
Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.		
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan. Defence Science and Technology Organisation - Australia (DSTO-AUS)	Collaboration	Automatic Identification System (AIS) tracking (Aguiar & Monte, 2011).
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan. Joint Forces	Collaboration	US Mil and joint forces events (Aguiar & Monte, 2011).
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.	Collaboration	Virtual NUWC library demonstration (Aguiar & Monte, 2011).
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.	Collaboration	4-Dimensional (4D) data visualization toolset (Aguiar & Monte, 2011).
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.	Rapid prototyping	A notional Virginia class attack center was built on an OpenSIM server during the summer of 2009. (Aguiar & Monte, 2011).No further details provided in the surveyed literature.
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.	Navy Training, Concept development, and experimentation	A secret level OpenSIM (multi-lab, with Air Force and Army partners) deployed in the spring of 2010 that provides a secure Department of Defence (DoD) vWorlds training environment, in which each of the DoD components build their specific pieces of a larger federated, virtual replication of the contemporary operating environment. The environment

OpenSIM User Community	Application Domains	Example Applications
		can be used stand alone or interactively in near real time with external live and virtual platforms, although specific details are not available in the report. Section 4.2.3.2 describes an experiment to validate the training performance of operators conducting target motion analysis using real systems in comparison to vWorlds systems. (Aguiar & Monte, 2011).
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.	Navy Concept development experimentation	Virtual C2 demonstration (Aguiar & Monte, 2011).
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.	Navy Concept development experimentation	Integrated Battlespace Awareness Layout (iBAL) experiment (Aguiar & Monte, 2011).
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.	Collaborative Naval Command and Control engineering desing and development tasks as well as concept of operation exercises (COOPEXs).	Virginia Block IV COOPEX (Aguiar & Monte, 2011).
US Navy, Naval Undersea Warfare Center (NUWC) Newport members including: Douglas Maxwell, Steven Aguiar, Philip Monte, Diana Nolan.	Navy C2 collaborative engineering and concept of operation exercises (COOPEXs).	360 Degree periscope human factors study (Aguiar & Monte, 2011).
US Navy Postgraduate School members including: Walt Scacchi, Craig Brown, and Kari Nies.	Joint military operations, concept prototyping, testing, and experimentation.	A Decentralized (DECENT) C2 system platform implemented in OpenSIM which allows authors to rapidly create a functional C2 vWorlds analog, and populate it with users for concept prototyping, testing, and experimentation. Scacchi, Brown, & Nies (2012) cite experiments to investigate the efficacy of team organization, team dynamics, and training outcomes when done in the real world in comparison to a virtual world (e.g., Bergin et al., 2010; Hudson & Nissen, 2010, 2011; Wynn, Ruddy, & Nissen, 2010), although summaries

OpenSIM User Community	Application Domains	Example Applications
		of these efforts are not provided.
Florida Institute of Technology, Harris Institute for Assured Information, Department of Computer Science members including: Marco Carvalho and Richard Ford.	Multi-national operations	vWorlds C2 environments for military coalition operations. A prototype of the proposed capability was implemented and demonstrated as an extension to OpenSim (Carvalho & Ford, 2012).
University of Edinburgh, Artificial Intelligence Applications Institute, School of Informatics members including: Austin Tate, Jeff Dalton, and Stephen Potter.	Multi-national, multi-agency emergency response operations, collaboration and planning.	Virtual Collaboration Centre for Multi-National Planning Augmentation Team (MPAT)-type operations in SL and OpenSIM. The collaborative "intelligent room" or I-Room, is designed to draw on emerging information exchange technologies which provides intelligent and intelligible planning aides to participants (Tate, Dalton, & Potter, 2009).
US Army	Other training (combat)	MOSES is an exploratory effort designed to evaluate the ability of the Open Simulator to provide independent and secured access to vWorlds. http://opensimulator.org/wiki/Grid_List/MOSES

4 DISCUSSION

4.1 Systems Development

This section discusses the potential use of OpenSIM platform for systems development. Practical considerations are proposed to address some of the anticipated problems and missing requirements for effective use in design.

4.1.1 Issues

Common issues include:

- It is difficult to keep track of vWorld developments as there are many which in turn makes it difficult to assess developed characteristics that may be useful in a military context (Maxwell, 2009). The underlying software architectures of vWorld platforms are rarely disclosed or made open even when realized using Open Source Software (OSS) components. Thus, it is a major technical challenge to evaluate, assess or compare vWorld design trade-offs. This is true whether the vWorld has been developed for training purposes (e.g., Project Bluejacket, see Table 3-1) or used to support a collaborative engineering activity (e.g., potential for application during design of the operations room layout for the Canadian Surface Combatant ship). Therefore, a framework definition is required to help develop open architecture (OA) vWorlds that can exchange models and be maintained or expanded efficiently (Scacchi & Alspaugh, 2008; Scacchi, 2012);

- There is a lack of tools to support real-time, dynamic prototyping (creation or modification of simulation elements while the simulation is running). Maxwell et al. (2011) found that no vWorld platform had capabilities to both import models and edit those models in real-time. Each vWorld that was examined either supported mesh model importing (hence content re-use) or supported in-world building and live design collaboration in a proprietary, geometric-primitive format. For instance, Maxwell et al. (2011) found that vWorlds could import models into the environment, but options for modifying and adjusting the models were limited or nonexistent with the currently available vWorld user interfaces;

- Developing a secure vWorld that can be used on public networks is a major challenge that will require collaboration between the military and vWorld industry partners (Aguiar & Monte, 2011). The US Military Open Simulation Enterprise Strategy (MOSES[7]) is evaluating whether OpenSIM can effectively provide secured access to a vWorld. There are plans to develop secured/encrypted communications, user authentication with certificates, and integration/conformance with the DoD Virtual World Framework (VWF).[8] The VWF is under development to work with vWorlds such as OpenSIM MOSES, and Massively Multiplayer Online Role Playing Games (MMORPG) such as EDGE. Such developmental, secure environments are restricted to secure networks until it could be shown that they could reliably be used on an open network; and,

[7] MOSES. Retrieved on 05 February 2014. http://brokentablet.arl.army.mil/
[8] DoD Virtual World Framework. Retrieved on 07 February, 2014: http://en.wikipedia.org/wiki/Virtual_world_framework

- The psychological and sociological implications of moving activities (e.g., conferencing, training, collaboration and experimentation) into an immersive environment where the user is perceived first by their avatar and not their physical persona are largely unknown (Aguiar & Monte, 2011). More research is required to determine whether there are adverse consequences as well as benefits to working vicariously through an avatar.

4.1.2 Requirements

The focus of most C2 related work has been on the user interaction and the collaboration aspects of vWorlds (Aguiar & Monte, 2011). User interaction concerns how the user acts in the vWorld and how the vWorld affects the user's avatar. Collaboration involves what is needed to help stakeholders (people and organizations) achieve shared goals. The OpenSIM platform provides a set of capabilities that can facilitate collaboration within an immersive environment, however, much work is required to create functionality that would be desirable by military organizations (Smith, 2011). Capabilities should be developed by employing a user centred design approach that could conceivably exploit open-source software development.

The following are suggested capabilities derived from the reviewed literature that should be provided by a vWorld to support collaboration effectively. It is unclear whether all of these recommendations have been validated or are merely the opinions of the various authors. The basis for prioritizing the implementation of these requirements should be informed by the conduct of a user needs analysis, capabilities assessment and cost-benefit analysis to determine their validity unless supported by the scientific literature:

- Allow the users to communicate naturally as appropriate to the application. The prevalent form of communication between group members is verbal conversations, so a means for verbal communication should be common to most vWorlds, although apparently many only support text interfaces. (Aguiar & Monte, 2011);
    - Verbal communications options may include technologies such as Voice over Internet Protocol (VoIP), chat, a basic level of multi-media (e.g., streaming video onto display surfaces), virtual aids. The objective is to ensure that the users are not only viewing the information but are part of the information space (Maxwell et al., 2011);
    - Provide the means for gestural communication. Allow explicit gestures and other visual actions to be visible since they are done in direct support of the conversation and help convey task information. There are cultural differences with this capability that should be considered to reduce misunderstanding, particularly with international participants;
- Include the means for remote users to link into the vWorld via cell phones (Tate, Dalton, & Potter, 2009);
- Provide tools in the user interface that participants can use easily and collaboratively to modify designs or the virtual environment dynamically in real-time (Aguiar & Monte, 2011);
- Provide a means of protecting the work of multiple users editing shared models in real time, providing undo, branching and model recovery (both automatically and manually);

- Allow stakeholders to review the evolution of design decisions (Aguiar & Monte, 2011). Persistence, with links to source material, provides knowledge management and the rationale behind design decisions. The use of OpenSIM in this manner would enable DND/CAF to document and review system designs such as compartment layouts and team processes on naval platforms;

- Models should be maintained as technology evolves. Operating systems change and may no longer support old software or hardware required by the vWorld; software changes may no longer support old model definitions; hardware changes, making old software unusable; dependencies may be broken and old models may no longer function; and,

- Provide camera controls as they are important to the collaboration process (Maxwell et al., 2011). Camera controls should provide the means for users to quickly shift from different perspectives or viewpoints of the models. Seeing what you can see and seeing what you think others can see is important in collaborative design and review.

4.1.3 Practical Considerations

4.1.3.1 Validation

Modelling and Simulation (M&S) is commonly used in system design and with complex systems. As M&S technologies develop, they are often promoted for a wide range of purposes with little supporting evidence that they are effective. For example, Scipione (2006) conducted an experiment to assess different display technologies for detecting design flaws in computer assisted design environment. User performance in the more “advanced” technologies, such as the Data Wall™ and Cave™ displays was poor, possibly due to distracting elements of the novel, immersive environments, while performance on more traditional 2D and 3D displays was superior (although each had differing advantages). Thus validation (fitness for purpose) should not be assumed as “intuitively obvious” and the application of these technologies by users in the entertainment industry should not be considered evidence of effectiveness; similarly, subjective opinions of usefulness can often diverge substantially from observed performance metrics and realism is typically an ineffective surrogate for validity. M&S often deliberately abstracts elements to facilitate understanding (Smallman, 2005; Lintern et al., 1997).

Unfortunately, there is insufficient data in the scientific literature to make generalizable conclusions and research is required to establish the range of validity of technologies such as OpenSIM. Since complex system designs are iterative, such as in Spiral Development (Boehm 2000), this provides opportunities to study technologies such as OpenSim for effectiveness at various stages to gain an understanding of where it is effective, where it is not effective and where it is cost-effective relative to other approaches. Validation research can follow typical approaches for assessing effectiveness of procedures using sound experimental design: test the vWorld to determine if it can produce the desired result, compare the result to alternative methods (control group of tradition method; alternative technological approach; etc.), and assess the relative costs of the successful approaches.

4.2 Training

This section discusses the common issues and requirements of using the OpenSIM platform for training. Practical considerations are then proposed to address these issues and requirements.

4.2.1 Issues

Training issues include:

- Compared to conventional live training exercises, simulated scenarios lack the direct hands-on experience and face-to-face interactions that live exercises provide (Hsu et al., 2013). However, live training is expensive, time-consuming, and is not easily repeatable, making it difficult to assess consistency in training delivery standards. As well as being expensive, including a large number of participants for live training may not be practical. There is an extensive literature on the successful use of simulation for training and much is known about learning in a simulated environment (Salas et al., 2009). Unsuccessful attempts to exploit computer based training receive less exposure in the literature, although there are a few instances that demonstrate the need for scientific validation (Whitney et al., 2013a; 2013b);

- Matching training requirements to vWorld capabilities is a challenging endeavour. A level of effort is required first to understand the training objectives, i.e. the characteristics of what the student must accomplish within the vWorld to be deemed proficient for a particular role. The functions and tasks the student needs to perform should then be mapped to the features and capabilities of vWorld platforms. OpenSIM may not be the best platform given the tasks that need to be performed and its use should be considered within an instructional design approach;

- The topic of securing a game-based vWorld for military C2 applications is a major concern (Scacchi, 2012). As with any other shared networks, there are risks to being online in a shared vWorld and most vWorld technologies provide only very basic security mechanisms. Furthermore, game-based vWorlds may allow for new modes of malware that enable activities including avatar impersonation or remote control (e.g., who/what is controlling this avatar, and with what authorization?), and other ill-defined vulnerabilities (Scacchi, 2012). Technological solutions such as Virtual Private Networks (VPN), local private networks and distributed leased lines may be used to address security issues, as is current practice in other domains;

- Designing a system that deliberately shows different (and incongruent) views of the vWorld to different users is problematic, as much of the vWorld work has focused on making sure that different users are actually present in the “same” virtual space, even if they view it from different viewpoints (Carvalho & Ford, 2012). The design of a vWorld training system will likely include student and instructor views of the vWorld, each with their own unique set of tools to interact with the vWorld. For instance, the instructor may wish to control playback of the vWorld simulation scenario, assume the perspective of the adversary or perform after action reviews with users. OpenSIM does not currently offer many of these functions and thus may not be the right platform if such capabilities are required; and,

- Collective training of users with different security levels (such as may occur with multinational exercises) poses a unique challenge for military applications that will likely require real-time updates on information release and access control policies that must be enforced. This may require development of automatic security protocols within vWorlds such as OpenSim that may not have adequate level of user management or even the software administration tools to provide user management.

4.2.2 Requirements

Training in vWords must support the following elements:

- According to Maxwell (2009) the vWorld should be an optimized blend of simulation and game that leads the learner being motivated by, and immersed into, the purpose and goals of a learning interaction;

- Develop and refine performance metrics that can be applied to gauge the knowledge, skills and training needed;

- The vWorld must capture the essence of the “operational environment” and its standard operating procedures; this is consistent with training effectiveness studies that show high fidelity representations often add little benefit and may actually impair learning because of distracting features (Salas & Cannon-Bowers, 2001; Salas, Milham, & Bowers, 2003);

- An adequate user experience needs to be supported by means of the content and interfaces provided (Tate, Dalton, & Potter, 2009);

- Engagement models are not readily available in open source vWorlds so development effort would be required to build such models, however, experience from other combat modelling environments may be applicable, simplifying development;

- Support various levels of fidelity with respect to the number and nature of participants and the technology mediating the training;

- Ensure course material is targeted appropriately to individuals within the audience as well as to overall teams that participate within training environments; and,

- Provide a means to apply or relax the laws of physics of the vWorld application (Allen & Demcahk, 2011).

4.2.3 Practical Considerations

4.2.3.1 Directed Investigation of Training Effectiveness

Training is a complex endeavour that sometimes displays counter-intuitive results. Effective training typically requires a disciplined application of instructional design, applying what is known about how people learn, how learning can be disrupted and how technologies support learning. There is a generally held impression that immersive environments that are realistic and engaging are better learning environments but that is a simplistic perspective. There is a substantial literature on the usefulness of simulation technology that supports learning, but the use of vWorlds for training is still in its infancy. There is some empirical evidence that vWorlds may be useful (Bailenson et al 2006, 2008, Dede 2009) but generally the effect sizes are modest to small. Nevertheless, vWorld technologies such as OpenSIM can be reasonably expected to be both effective and affordable in many situations provided they are applied in an informed manner following instructional design principles and the wealth of scientific literature on instruction simulation technologies is considered.

4.2.3.2 Validation

Validation of a vWorld for learning and training can exploit a few approaches (AGARD 1980), but two in particular have been applied to validation of simulators. Both involve assessment of whether it is reasonable to expect that what is learned in the vWorld will transfer to the real world, although the approaches differ. The first is the gold standard: Forward Transfer of Training. This involves assessing a training program with a cohort of subjects in the simulator (in this case, the vWorld) and then putting the training cohort into the real world situation. A measure of performance is the learning curve and learning rate of the group, and whether the vWorld contributes to the learning curve advantageously. Comparison with learning in the real world situation is frequently used as a control and both effectiveness and cost-effectiveness should be considered when judging the overall performance of the intervention. A second approach, Reverse Transfer of Training, does not provide as definitive an answer, but may be an effective alternative when transferring the training cohort to the real world situation is expensive or risky. In the Reverse Transfer of Training approach, the learning curve of a learning cohort is compared to that of a domain expert cohort and the differences are used to predict training effectiveness of the (vWorld) training intervention.

Aguiar and Monte (2011) seemed to apply the Forward Transfer of Training method to validate the performance of fleet operators in a vWorld compared to a physical world. The experiment involved two teams of fleet personnel performing submarine Target Motion Analysis (TMA) to identify, classify, and track a contact of interest. Each team ran through a TMA scenario twice – one trial allowed the operators to access the submarine combat system from the actual Command and Control Center (CACC) hardware, and the other trial allowed access to the tactical systems via the vWorld CACC. While the number of participants in the study cannot be considered statistically significant, the study has revealed a number of lessons learned. The results of this experiment suggest that operators performed TMA equally well in both trials. The results also suggest that C2 operator activities from within a remote, distributed virtual environment are comparable (and thus measureable) to operation in the real environment. Similar experiments should be conducted with a larger number of participants in future experiments to assess team performance and vWorld performance compared to a baseline.

5 CONCLUSIONS & RECOMMENDATIONS

The conclusions of this work are:

- Several vWorld platforms are available that could be and are being applied to military domains (at least on an experimental basis) including: Second Life, OpenSIM, Virtual Battle Space 2 (VBS2) / VBS3, Active Worlds, Croquet, On-Line Interactive Virtual Environment (OLIVE), Open Colbalt Alpha, OpenEnergySim, Open Wonderland, Pivote and Teleplace;

- Converging trends reveal that OpenSIM is being demonstrated as a capable and flexible platform. There is an active OpenSIM user community in the application domains of interest to DRDC (Section 3.2) including organizations such as: US NUWC, DSTO, the US Navy Postgraduate School, Florida Institute of Technology (Harris Institute for Assured Information), University of Edinburgh (Artificial Intelligence Applications Institute), and the US Army;

- OpenSIM can support diverse applications including systems development and training, and the number of institutions exploring vWorlds in general seems to be increasing as awareness of the technology increases. However, the scientific literature assessing the validity of vWorlds for training or analysis is immature and the effectiveness of these technologies remains to be determined;

- Research and development or at the very least knowledgeable analysis is needed to match training requirements to evolving vWorld capabilities in order to establish the validity of a vWorld for the intended training application. Much of what is known about the effectiveness of simulation-based training should be applicable, but there are many misconceptions held by education practitioners;

- Basic research is needed to develop open architecture (OA) frameworks for specifying vWorlds to promote exchange and reuse of models as well as reduce the incidence of models that cannot be exchanged between virtual environments (Scacchi & Alspaugh, 2008; Scacchi, 2012); and,

- OpenSIM can be linked to other analysis tools through an Application Programming Interface (API).

Recommendations are:

- Employ a user centred design approach to develop tools fit for use in vWorlds for the purpose of systems development and training. In accordance with guidance from MIL–STD–46855A, the Mission, Function, and Task Analysis (MFTA) methodology has been widely used within the Human Factors community to conduct analyses of user requirements for over twenty years. Suggested capabilities derived from the reviewed literature that should be provided by a vWorld to support systems development and training effectively are documented in Section 4.1.2 and Section 4.2.2, respectively;

- Conduct a number of use-case experiments that compare vWorld development to conventional design methods to assess the relative costs and effectiveness of immersive environments for design. The use-cases should be sufficiently challenging that they can

discriminate between the design approaches, but limited in scope so that they could be conducted in an affordable manner. Further, the experimental design should explicitly include adequate training in both traditional and vWorld design methods to minimize biases due to learning the methods per se (Scipione, 2006);

- Employ a disciplined, instructional design approach before considering vWorlds as a potential solution for training delivery;

- Conduct a directed investigation of training effectiveness. Effective training typically requires a disciplined application of instructional design, applying what is known about how people learn, how learning can be disrupted and how technologies support learning; and,

- Validate the use of OpenSIM for learning and training by employing transfer of training analysis methods as prescribed by AGARD (1980).

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7 LIST OF ACRONYMS

2D	2-Dimensional
3D	3-Dimensional
4D	4-Dimensional
AIS	Automatic Identification System
API	Application Programming Interface
AWEDU	Active Worlds Educational Universe
C2	Command and Control
CACC	Command and Control Center
CAF	Canadian Armed Forces
CATIA	Computer Aided Three-dimensional Interactive Application
CFB	Canadian Forces Base
COLLADA	Collaboration Design Activity
COOPEX	Concept of Operations Exercise
CVE	Collaborative Virtual Environment
DCC	Decentralized Command and Control
DECENT	Decentralized
DLSE	Director Land Synthetic Environments
DND	Department of National Defence
DoD	Department of Defence
DRDC	Defence Research & Development Canada
DSTO-AUS	Defence Science and Technology Organisation – Australia
DWAN	Defence Wide Area Network
ERP	Enterprise Resource Planning
FPS	First Person Shooter
HE	Human Engineering
HSI	Human Systems Integration
iBAL	Unknown
IDE	Integrated Development Environment
IPT	Integrated Product Team
I-Room	Intelligent Room
ITS	Intelligent Transportation System
JIMP	Joint Interagency Multi-National and Public
M&S	Modelling and Simulation
MFTA	Mission Function Task Analysis
MMORP	Massively Multiplayer Online Role Playing Games
MOSES	Military OpenSIM Enterprise Strategy
MPAT	Multi-National Planning Augmentation Team

MPML3D	Multi-modal Presentation Markup Language
NASA	National Aeronautics and Space Administration
NS	Nova Scotia
NUWC	Naval Undersea Warfare Center
OLIVE	On-Line Interactive Virtual Environment
OpenSIM	Open Simulator
Ops	Operations
PDF	Portable Document Format
SA	Scientific Authority
SL	Second Life
SOW	Statement of Work
TMA	Target Motion Analysis
US	United States
USB	Universal Serial Bus
USW	Under Sea Warfare
VBS2	Virtual Battlespace 2
VBS3	Virtual Battlespace 3
VE	Virtual Environment
VoIP	Voice over Internet Protocol
VPN	Virtual Private Network
VW	Virtual World
vWorlds	Virtual Worlds
VWF	Virtual World Framework
VWT	Virtual World Technology
XML	Extensible Markup Language

APPENDIX A ADDITIONAL INFORMATION

A.1 Search Results (Original Scope)

This section presents the search results for the original scope of work divided into categories based on whether they were subsequently approved for review or not. Most are presented as links to the documents.

A.1.1 Approved for Review: High Priority Items

US Army's Military Open Simulator Enterprises Strategy (MOSES) grid

- EdMedia - Military Open Simulator Enterprise Strategy
- Military Open Simulator Enterprise Strategy Components and Architecture 12.JUN.12
- MOSES MAP: Interactive region grid map with panning and zoom

OpenSim Grid List: A community generated list of virtual worlds.

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A.1.2 Approved for Review: Low Priority Items

OpenSimulator.org
- User documentation
- Getting started in Second Life and OpenSim

Second Life
- World Map
    - Destination Guide
        - About
- Search for groups in Second Life
- Events calendar
- Classifieds

Linden Labs, Inc.

Phoenix Viewer Project Inc.
- Wiki

RealXtend open source platform for the 3d Internet

The Command and Control Research Program - Experimental Laboratory for Investigating Collaboration, Information-sharing, and Trust (ELICIT)
- ELICIT Overview
- Publications
    - The ELICIT Experiment: Eliciting Organizational Effectiveness and Efficiency under Shared Belief
    - Hypothesis Testing of Edge Organizations: Laboratory Experimentation using the ELICIT Multiplayer Intelligence Game

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